A New Approach for Satellite Based GNSS Augmentation System: from Sub-meter to Better than 0.2 Meter Era

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BIOGRAPHIES

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ABSTRACT

In this paper we propose a new type of SBAS correction information: zone-correction. It is defined to augment to the existing SBAS long-term and fast corrections, and applies to regions covering up to one million square kilometers.

To evaluate the performance of the new zone-correction, we have design a data processing approach for a simulated SBAS system. In the first step, real-time data of a list of GNSS reference stations is used to calculate augmentation information, namely the long-term correction, fast correction, and zone-correction. In the second step, the augmentation information is broadcast to users through simulated streams. In the final step, user stations apply the augmentation information and perform real-time kinematic PPP to derive their positions.

GNSS data of the Crustal Movement Observation Network of China (CMONOC) is used to test and verify the new approach. We selected 20 well distributed stations of the CMONOC network as reference stations, and the other 240 stations are used for user positioning tests. One week data are processed and results show that convergence time of PPP using the new augmentation information is shorter than 2 minutes and positioning accuracy is around 0.1 and 0.15 meter in horizontal and vertical directions.

INTRODUCTION

The satellite-based augmentation system (SBAS) includes the US-American Wide Area Augmentation System (WAAS, GPSWAASPS 2008), the European Geostationary Navigation Overlay Service (EGNOS, Ventura-Traveset et al. 2006), and the Japanese Multi-functional Transport Satellite Satellite-based Augmentation System (MSAS, Nakaitani 2009) etc. The primary correction data streams of these systems include satellite orbit, clock, and ionosphere correction data for North America, Europe, and Japan respectively. The main objectives of these systems are providing integrity positioning with a safety-of-life quality and providing a better accuracy than stand-alone GNSS. They are expected to be used with single-frequency code observations. For more precise applications we could use the SBAS orbit and clock corrections together with dual frequency code and carrier phase observations to compute precise point positioning (PPP) solution.

Current reported user positioning accuracy of WASS could reach sub-meter. It is a big improvement over the legacy PNT (positioning, navigation, and timing) service. Its applications in real-time positioning with accuracy of 0.1-0.2 meter are limited. The bottleneck of the WAAS accuracy improvement lies in the accuracy of the correction information it broadcasts.

This paper proposes a new type of SBAS correction information: zone-correction. It is defined to augment to the existing SBAS long-term and fast corrections, and applies to regions covering up to one million square kilometers. We applied the new zone-corrections in the simulated SBAS-like augmentation system over China region. In this system, GNSS data of 20 continuous sites of the CMONOC network is defined as reference stations and the other 240 CMONOC stations are used for user positioning tests. One week data are processed and results show that convergence time of PPP using the new augmentation information is shorter than 2 minutes and positioning accuracy is around 0.1 and 0.15 meter in horizontal and vertical directions.

CURRENT SBAS AUGMENTATION INFORMATION

There are different augmentation information for current SBAS systems, and they are broadcast through the RTCA DO229 (RTCA 2006). The orbit and clock information in RTCA DO229 format is split into long-term and fast corrections. Long-term corrections contain information on the slowly varying satellite orbit and clock errors, whereas fast corrections provide additional information on the fast varying clock errors. Long-term corrections consist of position and clock offset values only (EGNOS) or they also contain velocity and clock drift corrections (WAAS, MSAS). The resolution of long-term position corrections and also of the fast corrections is 0.125 m, which limits the achievable accuracy of the PPP results. Applying these SBAS augmentation information, Heßelbarth and Wanninger (2012) investigated their performance over service region using the PPP method. The following table show their findings. Among the three SBAS, WAAS produced the by far best results. Coordinate RMS values indicate a 10–30-cm accuracy level. EGNOS and MSAS results are worse by a factor of about 3. Orbits and clock corrections of the GPS satellite messages produced 3D-positioning results on the 2-m accuracy level.

Table 1. RMS values of all epoch-by-epoch PPP coordinate solutions in north/east/up (cm), Heßelbarth and Wanninger (2012)

Region	Broadcast	SBAS		
		WAAS	EGNOS	MSAS
USA	55.9/122.7/134.6	13.6/25.7/30.7		
Europe	70.3/128.2/150.7		3.2/68.1/100.2	
Japan	55.2/123.6/174.1			36.6/74.3/112.0

ZONE-CORRECTIONS

Orbit correction is intend to fit the orbit error of the broadcast ephemeris to the minimum value. However, the accuracy of parameter estimation is limited due to the big DOP (dilution of positioning) value caused by the poor tracking capability. Moreover, orbit correction is highly correlated with clock parameter, which further makes the parameter estimation difficult. Consequently, the positioning performance of SBAS system is limited to the level listed in the above table.

The SBAS system provides additional information compensating the un-modeled errors for regional users. Based on similar idea, ground-based augmentation system (GBAS) develops more types of correction information and broadcast them via internet protocol, which has more bandwidth allowing higher sampling and more information to be broadcast. Comparing to the SBAS system, the GBAS system covers smaller region and its performance precision is higher.

Zone-correction (Chen et al. 2015) is defined as the augmentation information for a zone. It represents the errors introduced by mis-modeled orbits, clocks, troposphere and ionosphere etc. The performance of zone-correction depends on the size of the zone, i.e., it could achieve similar positioning accuracy as a GBAS system when the zone is small as the service area of a GBAS system, and its performance is similar to a SBAS system when the zone is as large as the service area of a SBAS system.

DATA SETS

Crustal Movement Observation Network Of China is in operation since 1999. It is a fundamental facility which has wide-range applications in diverse areas with high precision and high spatial resolution. It consists of 260 GNSS stations, several Very Long Baseline Radio Interferometry (VLBI) and Satellite Ranging (SLR) and precise leveling and gravity stations. Figure 1 shows horizontal velocity field of the CMONOC GNSS stations (Chen et al. 2014). We selected 20 well distributed stations of Figure 1 as reference stations to derive the zone-correction, and the other 240 stations are used as user stations for PPP positioning tests.

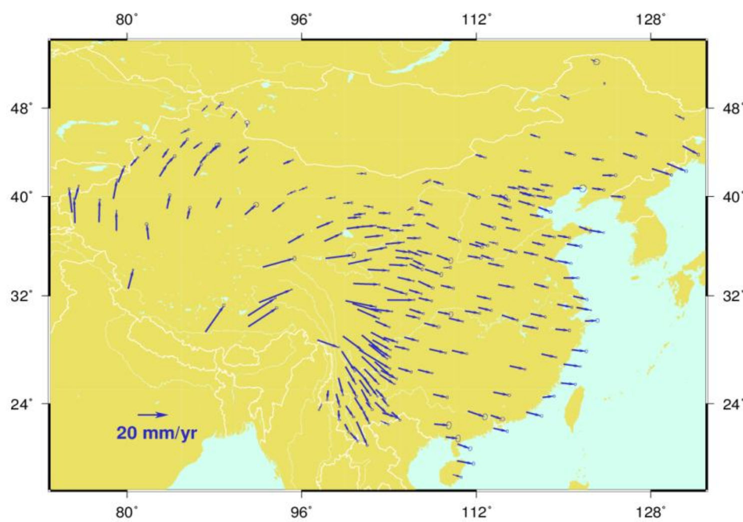

Figure 1. The horizontal velocity field of CMONOC stations, data of all these stations is used for zone-correction performance evaluation.

Data processing scheme is designed as following: in the first step, real-time data of a list of GNSS reference stations is used to calculate augmentation information, namely the long-term correction, fast correction, and zone-correction. In the second step, the augmentation information is broadcast to users through simulated streams. In the final step, user stations apply the augmentation information and perform real-time kinematic PPP to derive their positions.

TEST RESULTS

One week data is used, kinematic PPP is performed for each user station. The design of zone size varies from few kilometers to around 1000 kilometers. RMS statistics of the kinematic coordinates are used to quantitatively assess the extrinsic positioning quality.

Figure 2 shows for each station mean positioning accuracy with respect to the zone size, where

RMS is calculated by comparing kinematic PPP coordinates to known true values. From figure 2, we see that mean horizontal position accuracy is 0.12m in RMS and 0.26m in 95% confidence. The vertical position accuracy is 0.16m in RMS and 0.36m in 95% confidence. In both horizontal and vertical directions, there is a linear trend between positioning accuracy and zone size. Figure 3 shows for each station mean convergence time for kinematic PPP of all stations, where convergence is defined as kinematic coordinates within 1 meter range of true values. From figure 3, we see that mean convergence time is 2.07 minutes and 95% are shorter than 7.5 minutes.

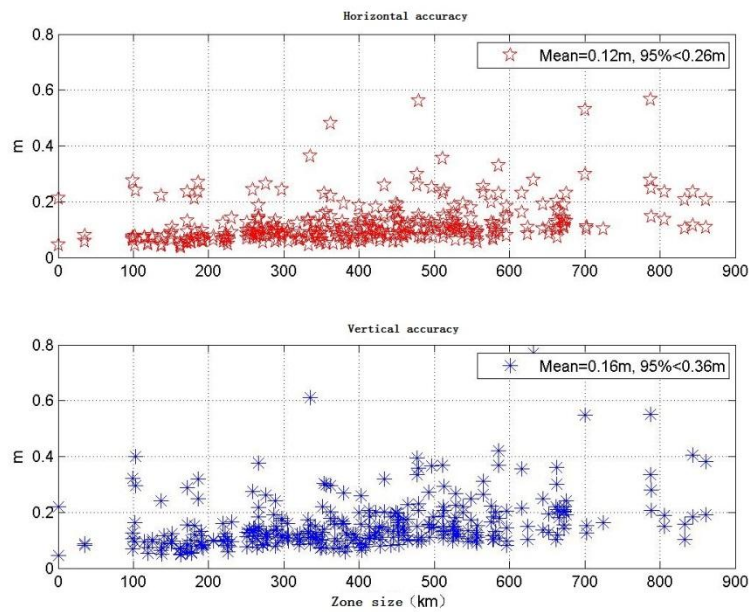

Figure 2. Mean positioning accuracy of all stations, where zone size is defined as the distance between user station and reference stations.

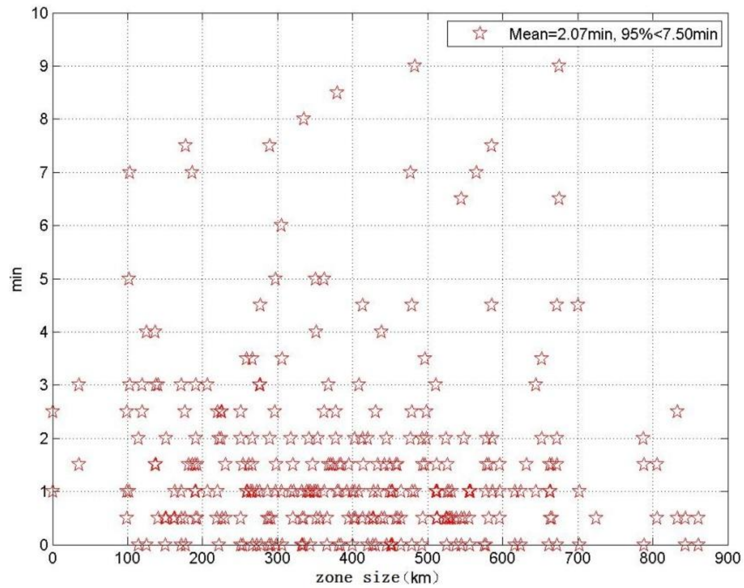

Figure 3. Mean convergence time for kinematic PPP of all stations, where zone size is defined as the distance between user station and reference stations.

CONCLUSIONS

In this study, we introduce zone-corrections as a new SBAS augmentation information. To evaluate the performance of the zone-corrections, we design a data processing approach simulating SBAS system, and the GNSS data of the CMONOC network is used for testing.

We analyze the performance of new augmentation correction using one week data of the 260 stations of the CMONOC GNSS network. Results show that the convergence time of PPP using the new augmentation information is shorter than 2 minutes and positioning accuracy is 0.12 and 0.16 meter in horizontal and vertical directions. These results demonstrate the decimeter level accuracy of SBAS system by introducing the zone-correction as new augmentation information. Further studies include the design of broadcast protocol and evaluation of the information updating interval.

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